

FE-BEARING PHASES IDENTIFIED BY THE MÖSSBAUER SPECTROMETERS ON THE MARS EXPLORATION ROVERS: AN OVERVIEW. R. V. Morris¹, G. Klingelhöfer², D. W. Ming¹, C. Schröder², D. Rodionov², A. Yen³, R. Gellert⁴, and the Athena Science Team. ¹ARES, NASA Johnson Space Center, Houston, TX 77058 (richard.v.morris@nasa.gov). ²Institut für Anorganische Chemie und Analytische Chemie, Johannes Gutenberg-Universität, Staudinger Weg 9, 55128 Mainz, Germany. ³Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109. ⁴Depart. Physics, University of Guelph, Guelph, Canada.

Introduction: The twin Mars Exploration Rovers Spirit and Opportunity have explored the martian surface at Gusev Crater (GC) and Meridiani Planum (MP), respectively, for about two Earth years. The Mössbauer (MB) spectrometers on both rovers have analyzed an aggregate of ~200 surface targets and have returned to Earth information on the oxidation state of iron, the mineralogical composition of Fe-bearing phases, and the distribution of Fe among oxidation states and phases at the two landing sites [1-7]. To date, 15 component subspectra (10 doublets and 5 sextets) have been identified and most have been assigned to mineralogical compositions. Two subspectra are assigned to phases (jarosite and goethite) that are marker minerals for aqueous processes because they contain hydroxide anion in their structures. In this paper, we give an overview of the Fe-bearing phases identified and their distributions at Gusev crater and Meridiani Planum.

Martian Fe-bearing phases, according to Mössbauer spectroscopy: In the following paragraphs, we identify the Fe-bearing phases in two ways. One is a generic name that refers to its oxidation state and whether the phase is characterized by a doublet or sextet subspectrum. For example, Fe2D1 and Fe3S1 refer to Fe²⁺ doublet subspectrum #1 and Fe³⁺ sextet subspectrum #1, respectively. The second identification is the mineralogical assignment for the subspectrum. Why two names? The generic name is not subject to interpretation and therefore not subject to revision. In contrast, the mineralogical assignment can be contentious and subject to possible revision as our understanding of Mössbauer datasets improves and Mössbauer results are integrated with information from other MER instruments. Except for newly detected subspectra, details concerning the values MB parameters are reported in [1-3].

Fe2D1 (oct-Fe²⁺, olivine). Olivine occurs in basaltic soils at both landing sites and in float rocks on the Gusev plains (Adirondack class basalts) and in the Columbia Hills. It is less common in outcrop rocks at West Spur and the summit region of Husband Hill. There is an extensive, olivine-rich outcrop along Haskin ridge (rocks LarrysBench through ComancheSpur). A nearby basaltic soil (ElDorado) is anomalously enriched in olivine.

Fe2D2 (oct-Fe²⁺, pyroxene). Like olivine, pyroxene occurs in basaltic soils at both landing sites. Pyroxene is the major Fe-bearing silicate component in many West Spur and Cumberland ridge rocks. BounceRock at MP is nearly all pyroxene with respect to its Fe-bearing phase.

Fe2D3 (oct-Fe²⁺, ilmenite). Ilmenite occurs in rocks located in the summit region of Husband Hill.

Fe2D4 (oct-Fe²⁺, probable chromite). Chromite is found in only two rocks near the Husband Hill summit (Independence and Assembly).

Fe2D5 (oct-Fe²⁺, possible pyroxene). This assignment is tentative. The doublet occurs only in two samples near the Husband Hill summit (Independence and Assembly).

Fe2D6 (oct-Fe²⁺, possible pyroxene). This assignment is tentative. The phase is present only in the olivine-rich rocks near Haskin ridge, and it is most abundant in the rock ComancheSpur.

Fe3D1 (oct-Fe³⁺, npOx). Nanophase ferric oxide is a poorly crystalline alteration and weathering product and occurs ubiquitously in basaltic soil, especially in fine-particulate soils where the dust component is high. Many rocks on Husband Hill (West Spur and the summit region) have high proportions of npOx. Fe³⁺ in crystalline silicate phases may have significant contributions to Fe3D1 when the proportion of total Fe associated with Fe3D1 is very small (e.g., the interior of Adirondack class rocks).

Fe3D2 (oct-Fe³⁺, sulfate). The Fe³⁺-bearing sulfate occurs only in the PasoRobles soil on Husband Hill.

Fe3D3 (oct-Fe³⁺, unassigned). This unassigned Fe³⁺-bearing phase occurs at MP and its abundance is highly correlated with the abundance of jarosite. Possibly, it is a form of npOx with somewhat different MB parameters.

Fe3D4 (oct-Fe³⁺, jarosite). Jarosite is a ubiquitous Fe-bearing phase in the sulfate-rich outcrop rock at MP. Jarosite is a marker mineral for aqueous, acid-sulfate process, because its structure contains the hydroxide anion and it precipitates under aqueous conditions at low pH.

Fe0S1 (Fe⁰, metal). Fe metal is found in only in Heat Shield rock at MP.

Fe2.5S1 (oct-Fe^{2.5+}, magnetite) and Fe3S1 (tet-Fe³⁺, magnetite). Magnetite is a minor component in basaltic soils and many rocks (e.g., Adirondack class basalt). It is a major component in a number of float and outcrop rocks in the Columbia Hills (e.g., Peace, Irvine, and Hillary)

Fe3S2 (oct-Fe³⁺, hematite). Hematite is a minor component (subordinate to magnetite) in most basaltic soils. It is abundant in many Columbia Hills float and outcrop rocks (PotOfGold, Watchtower, and Keel). At MP, hematite is a major component in the sulfate-rich outcrop and possibly the only Fe-bearing phase in the spherules (blueberries). In many samples, the Morin transition is apparent.

Fe3S3 (oct-Fe³⁺, goethite). Goethite occurs in Columbia Hills rocks, especially at West Spur. It is a major Fe-bearing component in the rock Clovis. Goethite is a marker mineral for aqueous process, because its structure contains the hydroxide anion.

References: [1] Morris R.V. et al. (2004) *Science*, 305, 833-836. [2] Klingelhöfer G. et al. (2005), *Science*, 306, 1740-1745. [3] Morris R.V. et al. (2006) *JGR*, in press. [4] Yen et al. (2005) *Nature*, 436/7, doi:10.1038/nature03637. [5] McSween H.Y. et al. (2006) *JGR*, 111, doi:10.1029/20. [6] Goetz W. et al. (2005) *Nature*, 436/7, doi:10.1038/nature03807. [7] Ming et al. (2006) *JGR*, in press.